The Capacity analysis of a Bypass with Paved Shoulder, in Bhawanipatna, Western Odisha

Abstract. The urban sprawl, in Bhawanipatna township is due to the rate of population surge and connectivity, migration, and construction of a hydropower station nearby. The resultant effect can be attested with considerable traffic jamming in peak traffic hour's accidents and crashes. In order to address the problem, the transport infrastructure needs expansion, upgrades, and rehabilitation of roads or diversion of traffic at the entry and exit points. The traffic congestion and delay in travel time can be alleviated by constructing a ring road or a bypass to relax from future repercussions. The objectives of present search is for finding an appropriate alternative to the traffic congestion of the township by evaluating the traffic capacity of the township, Classified Traffic volume count (CVC), and AADT (annual average daily traffic volume), ADT (Average daily traffic), economic analysis, and social impact assessment. The fast-growing Bhawanipatna Town has increased during the last decade due to industrialization, urbanization, and improvement of existing highway infrastructures. The traffic congestion caused in Bhawanipatna town can be alleviated either by constructing a ring road or a bypass for the Highways. The outcome recommended for the alternate road diversion morphogenesis is a bypass pass through the town with a paved shoulder obtained from the economy/capacity analysis and at the cost of urban greenness cover.

Keywords: Bypass, Ring road, Capacity analysis, paved shoulder, Traffic congestion, urban sprawl,

Introduction

The Bhawanipatna, the headquarter of the district Kalahandi (Atavika land), is housed in southwest (SW) Odisha (19°N and 21.5°N lat., and 82.20°E and 83.47°E long., part of the Eastern Ghats Belts (EGB). The district borders other districts like Balangir, Nuapada, Koraput, Nabarangpur, Rayagda, Boudh and Kandhamal. The Bhawanipatna uplands consequence the rolling uplands, but nutrient-rich soil is at a lower altitude than the plateaus (varying from 153 m. to 305m.), The uplands are formed in the undulating topography surrounded by the river Hati but a series of hilly terrain (**Fig 1** (a) & **Fig 1 (b)).**

The Bhawanipatna town receives the maximum average annual rainfall of 1378.20 mm during the SW monsoon season. The atmospheric maximum temperature ranges 4°Cduring winter to more than 45°C during the peak summer season. The demography of the district is dominated by the Scheduled Caste and aboriginal Tribal people but the district-wise literacy is 85.00 % greater than the average of literates in Odisha of 72.87 %. The total urban population is 69045, out of which males and females are 35506 and 33,539 respectively (Census India, 2011). The projected area expanded by 2020 is 938.89 km², accommodation Population of 234319 at a density of 249 people/km². The Bhawani Patna Municipality comprises 20wards and lives in about 15600households. The Hati River Project, a part of the Upper Indrāvati multipurpose project and the powerhouse at nearby Junagadh has changed the economy and yield from agriculture. The surged population and economy have warranted a ring road around the city to accommodate the rising traffic volume.

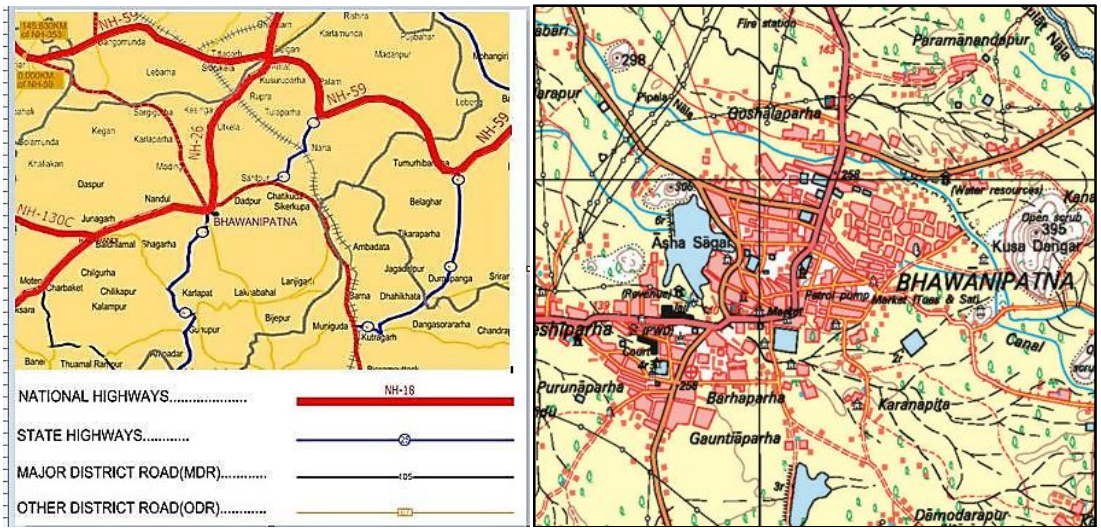

Fig 1: (a) The road map and (b) the drainage map of the Bhawanipatna area

The primary objectives of the study are to evaluate the existing road and traffic conditions, and the growth potential of the influence area and to suggest appropriate improvement schemes for the Project Roads.

Kalahandi district has a total road infrastructure of 1120.75km comprising State Highway (S.H.) of lengths 240.567Km, Major District Road (M.D.R) of 187.74Km, and Other District Road (O.D.R) of 692.444Km. and all the major activities are concentric at its district Headquarters at Bhawanipatna. It is connected mainly through intra district; inter district, and interstate by National Highways (NH-26), three numbers of state highways, S.H.-6, S.H.-16, S.H.-44, and one ODR (Table 1).

Table 1: The NH, S.H., and O.D.R passing through adjoining the Bhawanipatna Municipal areas

#	Road Type	Old designated	Presently assigned	Total Length Road (Odisha)	Area joining
1	**N.H.**	201 (AP) NH -43 (Odisha)	NH-26	A.P. - 90.33 Orissa 434.76	Start from NH-53 junk. near Bargarh pass Bhawanipatna, up to Koraput in Odisha, ending Natavalsa in AP with NH16.
2	S.H.	S.H.-6	S.H.-6	37.382Km	Bhawanipatna to Rayagada. Upgraded MDR to SH vide W/Dept. lr. no.11998 / 01.11.2016
3	S.H.	S.H.- 16	S.H.- 16	38.523Km	Bhawani Patna to Khariar; Upgraded MDR to S.H. (W/D lr. no.11998 / 01.11.2015
4	S.H.	S.H.- 44	S.H.- 44	54.294Km	Bhawanipatna to Gunupur (Kasipur) road. (from 0/0 to 55/5km)
5	ODR	ODR	ODR	1.954Km	Transferred to R&B Dept. from H.&U.D. Dept.vide W/D Notification No.8966 dt.31.07.2014

Source:MoRTH,https://morth.nic.in/sites/default/files/Details-of-National-Highways-as-on-31.03_1.pdf;and R&B Dept, Kalahandi, httpwww.worksodisha.gov.in/dpir_roadnetwrk_nc_Kalahandi

The National Highway, NH26 (present) has been renamed as NH43 and NH 201 (in past), is originating from the NH-53 junction near Bargarh passing through Bhawanipatna, up to Koraput in Odisha, and finally terminating at Natavalsa in Andhra Pradesh (AP) with NH16. The 525.1km long NH 26 runs 90.33km in Odisha and 434.76km in MP and passes through Bhawanipatna.

The Government of Odisha is planning to upgrade & rehabilitate the connectivity of roads between various important places in Odisha. PWD has been entrusted with the preparation of DPR for M/s CADD Consulting Engineers Pvt. Ltd, Bhubaneswar for development of NH network. MoRT&H has decided to take up the development of various National Highway stretches in the state of Odisha under Public Works Department (PWD) – National Highway Division.
Public Works Department (PWD) – National Highway Division, Odisha has been entrusted with the assignment of "Consultancy Services for Feasibility Study and preparation of Detailed Project Report for proposed Bypass at Bhawanipatna on NH-26 in the State of Odisha" has been awarded to M/s CADD Consulting Engineers Pvt. Ltd, Bhubaneswar. *The Project stretch comprises the following for a total length of 10.577 Km in the state of Odisha:*

2. Bhawanipatna Bypass

The summary of the search is to present the findings of the feasibility study report in a summarized manner. The project location is shown in Figure: 2 and the proposed Alignment on the satellite image are shown in Figure: 3.

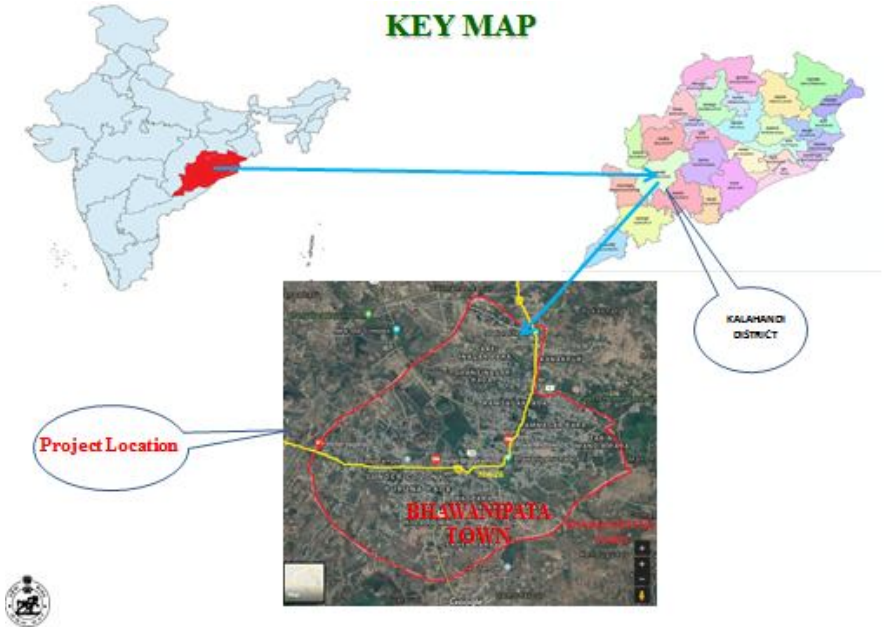

Figure 2: Index Map of Bhawanipatna Bypass (Source: Google

Figure 3: Proposed Alignment of Satellite Image

Review of Literature:

To upsurge the road's ability for accommodating congested traffic volume, peripheral ring roads (first built in the 1930s, around Berlin city), are built around a township in its initial stages of incubation. But later in long run, the traffic congestion rebuilds over the ring road area as the urban putative agglomerates, and changes in land use, Hall P., 1990[1], Martin et al., 2010[2], Nugmanova et al, 2019[3]. Urban road morphogenesis is diligently allied with its central and structuring components, directionally biased, mobility, and ease of access. Ring roads can ameliorate traffic congestion, reduces road traffic accidents, increase overall travel time, reduces unintended issues of health, and protect the environment (Thomson et al., 2008[4], Lee et al., 2017[5], Wang et al., 2019[6], Hatab et al, 2019[7], Dey et al., 2022[8], Raju et al., 2022[9], Gouj et al., 2022[10])

Bypasses are road circumvents for small sized considered to be the cheaper, and more effective tool to reduce traffic congestion within a city by diverting heavy cargo traffic that causes unwanted environmental, social, and land use bearings, like pollution, accidents, deaths, pandemics, crashes, GHG's, fumes, noise, and vibration (Goyal et al., 2016[11], Kumar et al., 2019[12], Bagh et al., 2022[13], Loo et al., 2022[14].

The choices of transport infrastructure to alleviate the traffic congestion within a busy city are ring roads, bypasses, roundabouts, elevated highways, vehicular underpass, etc, Choudhury et al., 2019[15], Subhalexmi et al., 2020[16].Arfin et al, 2020[17], Das et al, 2021[18].

3. Project roads

Bhawanipatna bypass road under the present consultancy services contract needs to be constructed to 2-lane with Paved shoulder standard. The chainage (km stone) of starting & end points of these roads have been taken as per discussions with the client. Details of the Bypass are given in below table 2 & 3**.**

Table 2: List of the Project Roads – as per TOR

S. No.	As per ToR	
	Name of the Project Road	Km
1	Bhawanipatna Bypass	10.590

Table 3: Start and End point of Project Roads – as per Design

Sl. No.	As per Preliminary Design					
	Name of the road	**From (Existing Km)**	**To (Existing Km)**	**From (Km)**	**To (Km)**	**Length (km)**
1	Bhawanipatna Bypass	171.805	184.190	171.805	182.382	10.577
	Total length					**10.577 Km**

4. Approach and Methodology

The improvement schemes so suggested based on the study would relieve traffic congestion along the route and bring about savings in vehicle operating and total transportation costs. The bypass for Bhawanipatna town would promote user comfort, safety, and environmental standards.

The methodology adopted is for the preliminary design has been based on a sound professional practice widely followed for similar upgrading/rehabilitation proposals. The existing standards and practices in the country in respect of design, construction, and maintenance of roads and the resource availability constraints have been duly kept in view while formulating the improvement proposals. The general guidelines given in the relevant Indian Roads Congress (IRC) Publication have been adopted as the Design Standards for the Study. Suitable modifications/ additions have been incorporated to suit local conditions and study requirements. The objective of the exercise has been adapted to have an optimal utilization of funds without sacrificing technical requirements.

4.1. Design standards and specifications

Guidelines for geometric standards for various types of roads in India are contained in IRC: 73-2018[19]. However, suitable modifications/additions have been incorporated to suit local conditions and study requirements. General principles of a typical cross-section and its application are described below:

4.2.New Construction in Bypass;

The provision of the bypass with 2 lane configurations has broadly been decided based on the following parameters:

1. The unsuitability of the existing carriageway to receive overlay;
2. Non-availability of ROW and possibility of acquisition of additional land if required;
3. Land use type along the existing alignment i.e. built-up;
4. Position of roadside plantation i.e. giant tree on one side or both sides
5. Geometric improvement requirements

4.3.Traffic capacity:

Indian roads congress (IRC) has recommended capacity values for various lane configurations in IRC: 64-1990[20]: Later the traffic capacity has been revised in clause 2.17 of manual & specifications IRC SP: 73-2018[19].

The Design Service Volume adopted as per IRC SP: 73-2018[19] for capacity analysis is given below:

For Two lane road

Plain Terrain	-	10000 PCU's/day
Rolling Terrain	-	8500 PCU's/day
Mountainous and Steep	-	6000 PCU's/day

These values of Design Service Volume have been kept in view while considering improvement proposals for the project road.

4.4.Traffic surveys and data analysis

Classified Traffic Volume Count (CVC) was carried out for seven days for each traffic homogenous section in April 2019. The summary of traffic volume counts is presented in (Table 4). Total AADT at this survey location was recorded as 5907 & 7710 in terms of number and 6205 & **7211** in terms of PCU (IRC 102; 1988[21]).

Table 4: Summary of Classified Volume Count Survey – AADT

Vehicle Type	Km. 173.800			Km. 185.244		
	To Kesinga	To Bhawanipatna	Both Directions	To Junagadh	To Bhawanipatna	Both Directions
Cycle	433	419	852	470	473	943
Cycle Rickshaw	8	6	14	1	4	5
2 W	1308	1391	2699	2307	1953	4260
3 W	89	90	180	118	118	237
Car/Jeep/Van	594	526	1120	625	621	1247
Mini Bus	24	25	49	12	13	24
Std. Bus	58	52	109	75	72	146
LCV	158	156	315	170	178	348
2 Axle Truck	95	90	185	66	70	136
3 Axle Truck	53	61	114	65	55	120
Multi Axle Truck	62	57	119	49	57	106
Tractor with Trailer	50	42	92	64	62	126
Tractor without Trailer	8	6	13	3	6	9

Vehicle Type	Km. 173.800			Km. 185.244		
	To Kesinga	**To Bhawanipatna**	**Both Directions**	**To Junagadh**	**To Bhawanipatna**	**Both Directions**
Animal Drawn	2	4	6	0	0	0
Other	1	2	3	1	2	3
Tollable Traffic (Vehicles)	1044	967	2012	1061	1067	2128
Tollable Traffic (PCUs)	1904	1808	3712	1869	1910	3779
Total Traffic (Vehicles)	2960	2947	**5907**	4025	3685	**7710**
Total Traffic (PCUs)	3146	3059	**6205**	3672	3539	**7211**

4.5.Engineering surveys and investigations

Right of Way: The scope of the Project is basically for new construction of the project road of 2-lane with paved shoulder standards. We are taken 45 m ROW for the new bypass Provision.

4.6.Improvement proposals and alternatives

The project road is completely Greenfield. The geometric improvements for the project roads, based on the design Standards evolved for the Study of Bypass, pavement composition, road junctions, Bridges and Cross Drainage, Special Problems, and Road Appurtenances.

The proposals for the new construction of the Bypass on NH 26 sections have been proposed based on the present and projected traffic volume and capacity. Based on joint site visits and various discussions with client's representatives, the improvement proposal for these locations is decided.

Pavement Design: The new flexible pavement is designed as per the guidelines of IRC: 37-2018"Guidelines for the Design of Flexible Pavements ("Fourth Revision")".

Structures: All new bridges have to construct newly as there are no existing bridges. The total section of the Bypass is completely new construction.

Based on the above, the improvement proposals in Project road are as follows

(i) Bridges are proposed for new construction. Hydrological calculations have been done according to the span arrangement of the structures that were proposed. At the DPR stage, flood frequency is evaluated for bridges that are recommended for new construction to evaluate the proposal based on HFL data collected.

The summary of the improvement proposals for structures is presented below:-

New construction of Box Culvert: - **2 Nos.**

New construction/reconstruction of Hume Pipe Culvert: - **17 Nos.**

New construction/reconstruction of Slab Culvert: - **3 Nos.**

New construction ROB:-**1 No.**
New construction of Vehicular under Pass (VUP):- **1 No.**
New construction of Light Vehicular under Pass (LVUP):- **1 No.**
New construction of Minor Bridge: - **5 Nos.**
No. of Major Junction: **3 Nos.**
No. of Minor Junction: **7 Nos.**

4.7.Environmental assessments

Environmental assessment is done to identify the potential impacts because of the proposed intervention and suggest suitable mitigation measures required to minimize negative impacts. The EA of proposed project roads is classified as low, medium, and high environmental impact category based on impact, availability of row, and development indicators of each road under present improvement. Further, the huge exploration of construction materials by local quarries shall deteriorate the solitary environment, and the rich biology of the outskirt of the town, Jang et al., 2022[22].

Along the project roads, tree counting was carried out to get the total number of trees existing within the 45 m Right of Way (ROW). It is found that 300 numbers of trees exist within 45 m of the corridor of different variety species. This shall deteriorate the urban greenness cover, environment, vegetation, and tranquility by enhancing pollution in the periphery of the present township, Dzhambov. et al., 2014[23], Gulia et al., 2022[24].

This project road falls under the medium impact category.

4.8.Social impact assessment and framework

Social assessment is done to identify the potential impacts because of the proposed intervention and suggest suitable mitigation measures required to minimize the negative impact because of the proposed road improvement. The purpose of the study is to understand the socio-economic characteristics of the project area based on socio-economic indicators and to identify significant social issues involved in project preparation one of the basic objectives of social assessment ensures that people are consulted; their opinion and preferences are considered during project planning. The important findings of the Social Assessment Study in the proposed project road of **10.577 km** length, one no. of the existing structure is found within the proposed ROW (Li et al., 2022[25]).

The land acquisition for the proposed road consists of agricultural lands, & dry lands,

The social assessment of proposed project roads is classified as low, medium, and high social impact category based on land acquisition, availability of ROW, development indicators of each road under present improvement, and status of the project road. The project road i.e., Bhawanipatna Bypass is in the medium impact category.

4.9.Preliminary Project cost

The costs of roads have been worked out on a per Km basis separately for the New Construction of Bypass in rural and urban sections. The cost of new structures has been calculated based on the running meter cost / per structure for pipe culverts, box/slab culverts, and bridges of different widths, spans, and heights of structures. The social cost relating to compensation to the affected PAP has been accounted for similarly environmental mitigation cost that has been accounted for by encroachment of the urban buffer zone.

4.10. Economic analysis

The project road section is economically viable even in sensitivity cases also. The project road is proposed to avoid the congested built-up area of NH-26 within Bhawanipatna town. The development of the project roads to 2-lane with paved shoulder standard will have a tremendous impact in reducing overall transport costs, including g time and accident costs, and improvement of the local economy. The economic analysis has indicated that the project gives an internal rate of return of over 12%. This must be considered to be an economically viable break-even point, being more than a discount. Further, the Sensitivity analysis also indicates that it is robust enough to withstand the worst situation of increasing costs by 20% and reducing benefits by 20%, where the rate of returns approaches 12% of the discount rate. Hence, the project road is economically viable and should be considered for implementation.

Result and Discussion:

The field data were collected for the structure bypass. The development of the bypass should include land acquisition, traffic survey, the nature of traffic, the terrain, and topography. Since the Bhawanipatna Township is expanding very fast, under uncertain growth of the township, the proposal for construction of a ring road thought not to be the present action plan may be kept for the future.

The present status of the people and the township do not need any ring road though flourishing fast. The ring roads not only divert the heavy carriages not entering the town, but also its efficacy lies in plummeting the traffic jamming, in urban with time run. The rate of growth of traffic and vehicles in the last decade has surged to be accommodated in existing transport infrastructure. So it is widely felt to go for infrastructural advancement to alleviate traffic congestion, Huang et al., 2022[26], Sahu et al., 2022[27], Patro et al., 2022[28].

The choice of a bypass or a ring road depends upon the length of the stretch, proximity of the national or State highway, demography growth rate, serving Population, vehicle registration, industrial growth rate, and finally the economic growth of the resident of the township. In addition to the existing land use pattern, there are questions about the availability, acquisition, and adjustment of land, and its developments. Bhawanipatna township though not a novice but its expansion has been faster after the construction of the powerhouse over the river Indrāvati, and the fast vehicular activities in the upgraded NH and SH. The choice of the bypass is the reduction of travel time and the driver's choice.

The bypass design proposal should deliver the service roads in parallel, signals, long-lasting roadside barriers to limit the entrance of local traffic, avoiding direct approach to the bypass; should not affect the neighboring land use planning, avoid the development of market complexes

in the vicinity, constructing control line norms, well planned considering future expansion of the township Van Nes et al., 2021 [29], Huang et al, 2022[26].

The economic analysis favors the internal rate of return of over 12% and is considered an economically viable break-even point, being more than a discount. Further, the Sensitivity analysis has pointed towards its robustness to withstand the worst situation of increasing costs by 20% and reducing benefits by 20%, where the rate of returns approaches 12% of the discount rate. Hence, the project road is economically viable and should be considered for implementation.

Conclusion and recommendations

Traffic jamming is an emerging major urban problem globally. Ring roads circumventing a township or a bypass are the paramount keys to alleviating the traffic congestion through a small or medium downtown.

The Bhawanipatna is an unplanned well connected old town housed in EGB Hills Range expanding very fast, discharge of chemical and poisonous effluents from the industries and market places are seriously affecting the water sources of the town. The bypass provision so suggested based on the study would relieve traffic congestion along the project road and bring about savings in vehicle operating and total transportation costs. The improved road conditions would promote user comfort, safety, and environmental standards.

It is observed from the capacity analysis that all the project roads shall be developed to 2lanewith paved shoulder standards. The paybacks shall increase regional accessibility and enhance cost-effective mobility.

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